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THE UNIVERSITY COLLEGE OF CAPE BRETON

DETERMINATION OF SLAKE DURABILITY INDICES OF LITHOLOGICAL UNITS SURROUNDING THE HARBOUR AND HUB SEAMS IN THE SYDNEY COALFIELD

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DETERMINATION OF SLAKE DURABILITY INDICES OF LITHOLOGICAL UNITS SURROUNDING THE HARBOUR AND HUB SEAMS IN THE CAPE BRETON COALFIELD

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SUMMARY

Production and safety problems are associated with mechanized coal mining when the underlying rock is inherently weak and/or susceptible to water softening. The Slake Durability Index is one means of measuring this weakness. The determination of slake indices,and the equipment and procedures used is described for over one hundred samples supplied by the geology department of the Cape Breton Development Corporation (CBDC). Sample sites are documented,data analyses performed, and a correlation between index and actual rock condition discussed.

On the basis of samples tested, Prince mine seat earths exhibited generally higher indices than those of the Lingan mine. CBDC should continue building up a database of indices for their properties and attention should be paid to verifying low seat earth indices in the Lingan-Phelan project area.

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LA DETERMINATION DES INDEX DE LA DURABILITE D'ETANCHEMENT DE LA PIERRE ENVIRONNANT LES VEINES DE 'HUB' ET 'HARBOUR' DANS LES DEPOTS DE CHARBON DU CAP BRETON

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SOMMAIRE

Les problèmes de la production et de la sûreté sont associés avec le charbonnage mecanisé quand la pierre autour de la veine de charbon est faible par inhérence et/ou susceptible à adoucir à l'eau. L'index de la Durabilité d'Etanchement est l'un des moyens pour mesurer cette faiblesse. La détermination de ces index et l'équipement et procédures utilisés sont décrits pour plus d'une centaine d'échantillons fournis par le département de la géologie de la Corporation de Développement du Cap Breton (CDCB). Les emplacements d'échantillons sont documentés, les analyses executées, et une corrélation entre l'index et la condition actuelle de la pierre est discutée.

Basée sur les échantillons testés, la pierre au-dessous des veines a la mine Prince indique généralement des index superieurs à ceux de la mine Lingan. Les CDCB devraient continuer à augmenter la base d'information des index pour leurs propriétés et ils devraient aussi vérifier les index inférieurs dans la région du projet 'Lingan-Phelan'.

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INTRODUCTION

Weathering reduces a rock's mechanical strength and increases its deformability, porosity and permeability. At the Cape Breton Development Corporation's (CBDC) coal mining operations in the Sydney area, weathering is being induced artificially as a consequence of the coal-cutting method employed. Large volumes of water for dust suppression, pick cooling, for avoidance of face conveyor jamming, and alternate drying during delays and between shifts are the causes. The resulting weakening of the proximate strata, particularly the underlying seat earth material, causes reduction in the rock's ability to withstand the bearing loads imposed by mining equipment. This ,in turn, is responsible for the settling into the rock of the equipment, necessitating the removal of considerable amounts of waste rock along with the coal during normal production operations. If the degree of weatherability of the various rock types that make up the seat earth units were predictable from samples, it may also be possible to better predict mining conditions far enough in advance so that appropriate arrangements could be made to compensate for floor weakness.

One of the measures of weatherability being used today is the Slake Durability Index. It is designed to assess the cracking and disintegration of rock samples when exposed to short term weathering processes of wetting and drying. Index tests are used to classify and compare one rock with another and, as such, are not actual measures. They basically simulate natural wetting and drying cycles, and are commonly used for classification and characterization of the softer rock materials, however, they can and are used for harder rock types.

CBDC's geology department provided samples which were taken from strata above and below the coal seams of the Prince and Lingan mines, as well as from the seams themselves, in addition to several core samples from the Lingan-Phelan drill-site. It was originally estimated that 200 samples could be tested over the period available, however, due to the shut-down of No. 26 Colliery (from where approximately one-third of the samples were to come),delays in equipment delivery,and time constraints imposed by regular fall classes starting up at UCCB, 117 samples were prepared and completed. This report describes the test equipment and procedure, documentation of sample sites, statistical results, analysis and recommendations for future work.

EQUIPMENT AND PROCEDURE

EQUIPMENT

The equipment used conforms to International Society for Rock Mechanics (I.S.R.M.) specifications and is essentially as follows:

A test drum fabricated from 2 mm standard mesh, unobstructed in length, 100 mm long and 140 mm in diameter, with a solid fixed base capable of withstanding a temperature of 105 degrees Celsius. It also has a solid removable lid sufficiently strong to retain its shape during use. Neither the exterior of the mesh nor the interior of the drum are obstructed by reinforcing members.

A trough contains the test drum and supports its horizontal axis allowing free rotation. It is filled with a slaking fluid such as water to a level 20 mm below the drum axis. The drum is mounted to allow 40 mm unobstructed clearance between the trough and the base of the drum. The principal features of the trough and drum assembly are illustrated in Fig.1., page 3. A motor drive rotates the drum at a speed of 20 rpm, +/- 5 per cent, for a period of 10 minutes.

Other units required were: (a), an oven capable of maintaining temperatures of 105 degrees Celsius, +/- 3 degrees, for periods of at least 12 hours; (b), a balance capable of weighing the drum plus sample to an accuracy of 0.5 grams.

PROCEDURE

(a) Representative samples were selected, comprising ten rock lumps, each weighing 40-60 g. to give a total sample weight of 450-550 g. Lumps were made roughly spherical in shape, and corners rounded during preparation.

(b) The sample was placed in a clean drum and dried to constant weight at a temperature of 105 degrees Celsius, requiring from 2 to 6 hours in the oven. The weight (A) of the drum plus sample was recorded and the sample immediately tested.

(c) The lid was replaced, the drum mounted in the trough and coupled to the motor.

(d) The trough was filled with tap water at 20 degrees Celsius, to a level 20 mm below the drum axis, and the drum rotated at 20 rpm for a period of 10 minutes.

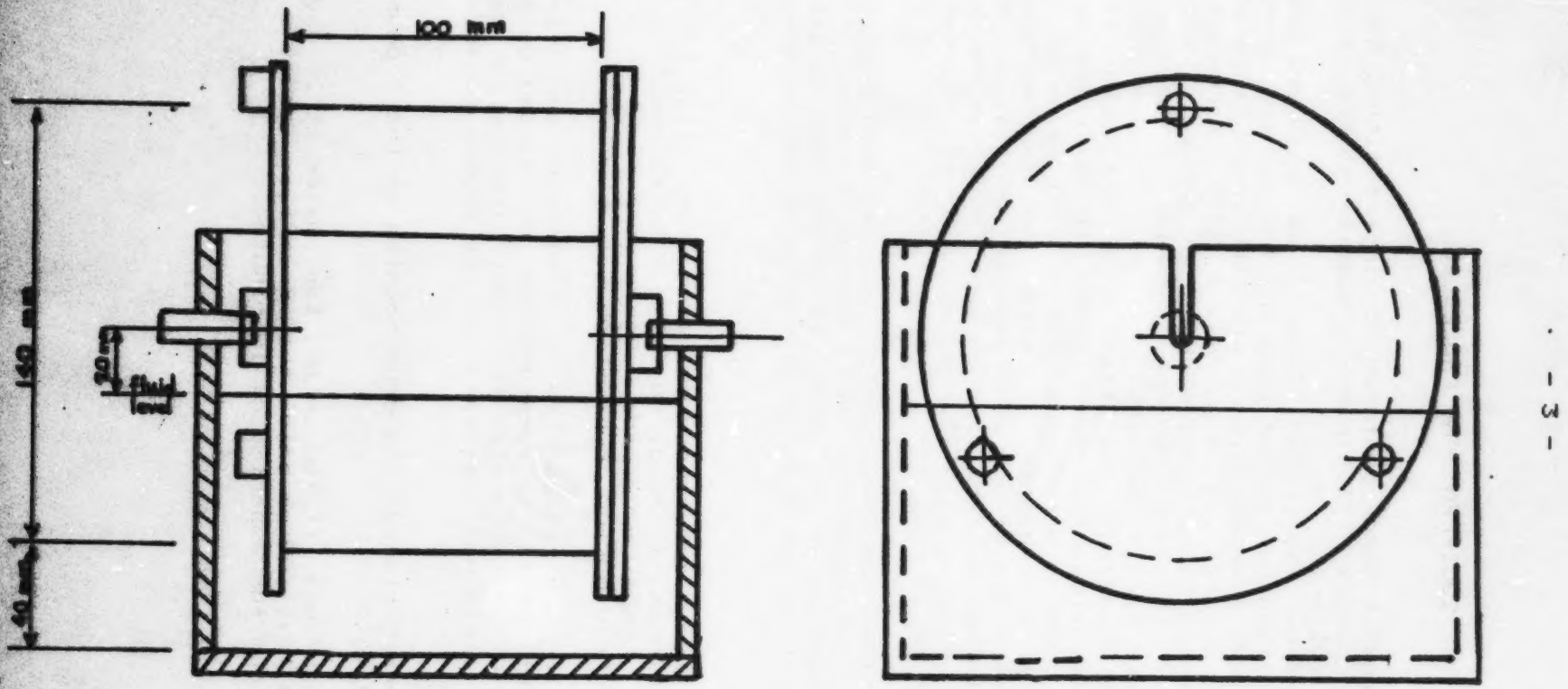

FIG. 1. Critical dimensions of slake-durability test equipment (after I.S.R.M., 1972; also FRANKLIN and CHANDRA, 1972).

(e) The drum was then removed from the trough, the lid removed from the drum, and the drum, plus retained portion of the sample, dried to constant weight at 105 degrees Celsius. The weight (B) of the drum, plus retained portion of the sample, was recorded.

(f) Steps (c) to (e) were repeated and the weight (C) of the drum, plus retained portion of the sample, recorded.

(g) The drum was brushed clean and its weight (D) recorded.

The Slake Durability Index (second cycle) was calculated to the nearest 0.1 percent as follows:

$$\text{Slake Durability Index, } ID(2) = C-D/(A-D)*100\%$$

The second cycle durability index, calculated as above, with tap water at 20 degrees Celsius, is proposed for use in rock classification. However, samples with second cycle indices from 0 to 10 percent are further characterized by their first cycle durability indices as follows:

$$\text{Slake Durability Index, } ID(1) = B-D/(A-D)*100\%$$

These indices are listed in Appendix 'A'. Sample collection sites have been documented according to their horizontal and vertical references and are listed in Appendix 'B'. Other information, such as; the nature and temperature of the slaking fluid, the appearance of the fragmented material remaining inside, and passing through the drum, is included in Appendix 'D'.

In addition to the contracted testing, and with the assistance of CBDC personnel, sieve analyses were done on the retained portion of the drum tests (material remaining inside of the drum) on the seat earth samples of Lingan and Prince mines and the drill core samples of the Lingan-Phelan project. Data obtained from these analyses are found in Appendix 'E'.

OBSERVATIONS

PRECISION

It was requested by CBDC that there be some check on the precision, or repeatability of the Slake Durability Indices on similar rock types. The first six samples provided for slaking were large enough so that duplicates could be prepared and tested separately. Table 1. below, indicates that the index for each sample compared favorably with its duplicate with the exception of samples PM-4 and PM-4(A). On inspection, it was observed that the lower-valued sample contained a higher proportion of carbonaceous material.

SAMPLE NO.	CBDC NO.	SLAKE INDEX (ID2)
1	PM-1	94.2
2	PM-1(A)	94.5
3	PM-2	86.6
4	PM-2(A)	84.6
5	PM-3	95.4
6	PM-3(A)	93.4
7	PM-4	75.1
8	PM-4(A)	60.3
9	PM-5	97.9
10	PM-5(A)	97.7
11	PM-6	93.9
12	PM-6(A)	94.4

Table 1. Test of Precision

DEGRADATION VALUES

Each sample tested, along with the calculated slaking index, was assigned a 'D' value. This serves to further qualify the sample on the basis of the degree of degradation of the portion remaining in the drum.

It was observed during testing that although two samples could have comparable slaking indices, the extent to which the sample degraded inside the drum could differ widely. As an example, a sandstone sample would have a high slaking index with no degradation of the remaining sample inside the drum, while at the same time, a mudstone also having a high index, could have the the remaining sample either partially or completely broken down, but not less than 2 mm, and so remained inside the drum. It was therefore decided to further qualify each test by appending a degradation (D) value as follows:

D Value	Degree of Degradation
0	none
1	light
2	medium
3	heavy

OTHER CLASSIFICATIONS

Another system for qualifying Slake Indices (Gamble, 1971),which adds a descriptive scale and appears to agree favourably with the 'D' values above and the known condition of the samples is as follows:

Index	Range
0-30	very low
30-60	low
60-85	medium
85-95	medium-high
95-98	high
98-100	very high

ANALYSIS

SAMPLE GROUPING

In order that statistics could be applied to samples with similar characteristics they were grouped as follows: The floor samples were divided by mine only. The bulk of the remaining samples were divided first by mine, then by rock type. Other samples, taken from areas of stone intrusions and core were dealt with separately.

STATISTICS

Table 2., following, shows the analysis of these groupings.

	Mean	Standard Deviation	Variance	Min	Max
LINGAN					
Sandstone	98.2	0.30	0.07	97.7	98.5
Siltstone	98.7	0.19	0.03	98.4	98.9
Mudstone	97.8	2.58	5.99	90.5	99.0
Coal	98.7	0.25	0.05	98.3	99.0
Floor	91.6	5.48	29.04	71.6	97.1
Intrusion *	98.2	(one sample)			
PRINCE					
Sandstone	95.3	1.05	0.98	93.9	96.6
Mudstone	82.2	12.77	135.86	60.3	95.5
Between rider and main					
Seam **	15.8	5.44	23.68	10.8	22.9
Coal	97.6	1.36	1.47	95.8	99.4
Splint	99.1	0.07	0.00	99.0	99.1
Intrusion *	96.8	0.64	0.27	96.4	97.6
Floor	93.5	3.75	13.45	83.9	97.9
CORE	75.1	7.25	39.44	66.4	84.0

* Local term for body of stone within coal seam.

** Due to very low second cycle indices, some first cycle figures were used in calculations.

Table 2. STATISTICS of SAMPLE GROUPINGS

DISCUSSION

SEAT EARTHS

The Prince floor is generally considered to be more competent than that of Lingan. One reason put forward for this difference lies in the nature of the seat earth below the seam. In the Prince floor, the rock is massive and more resistant to water penetration, while at Lingan the floor has heavily laminated horizontal sections giving easier access to water resulting in exfoliation. As seen in figures 2. and 3., page 9, the slake durability tests are consistent with this observation. The bar charts show a higher proportion of Gamble's 'high' vs 'medium high' values existing in the Prince floor compared to those of the Lingan mine floor. The statistics in Table 2. do not indicate this point as well since one cannot see the individual values. They do , however, show a higher mean and range for the Prince samples. A glance at the D values in the data (Appendix 'A'), on the other hand, suggest a significant difference: of the 29 Lingan floor samples, six of them, or 21 %, are in category 1. (light degradation), while the Prince floor samples have 12 of 23, or 52 % in the same category. However, these latter are subjective designations and must be treated as such.

ROOF STONE

The roof rock at both mines is known to be relatively strong locally, and this is confirmed by the high Slake Durability Indices and low degradation , or D values. The exception is the roof mudstone at Prince mine which has a mean index of 82.2 and a high degree of degradation.

In Appendix 'B' the sample sites are documented according to their plan co-ordinates and their vertical relationship to the seam. For a better look at the data, Appendix 'C' shows each sample grouping as a Frequency vs Slake Durability Index plot.

Lingan-Phelan Core

The core samples are from 'NQ'core (48 mm diam) taken from the seat earth intersections of four drill holes put down into the proposed Lingan - Phelan Project area. Indices were consistently low , with a mean index of 75.1 , and a range of 66.4 to 84.0. All core samples exhibited similar D values of 3; i.e.,heavy degradation of the material remaining in the drum after slake index testing.

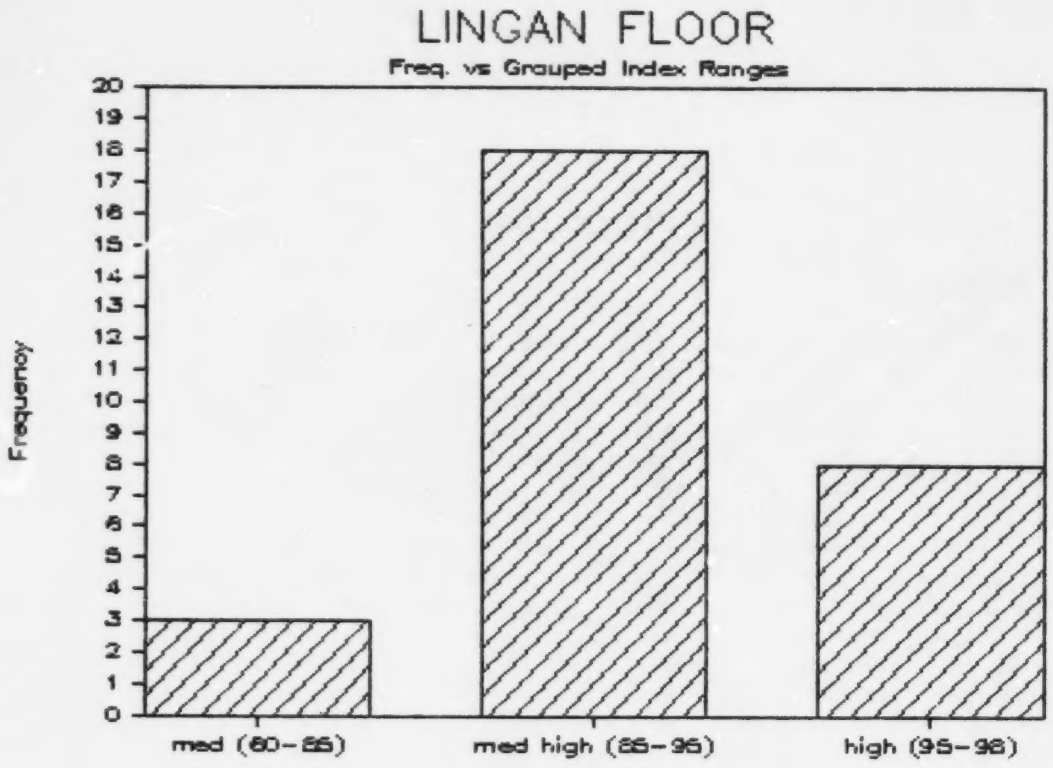

Fig.2 Durability Class'n (Gamble,1971)

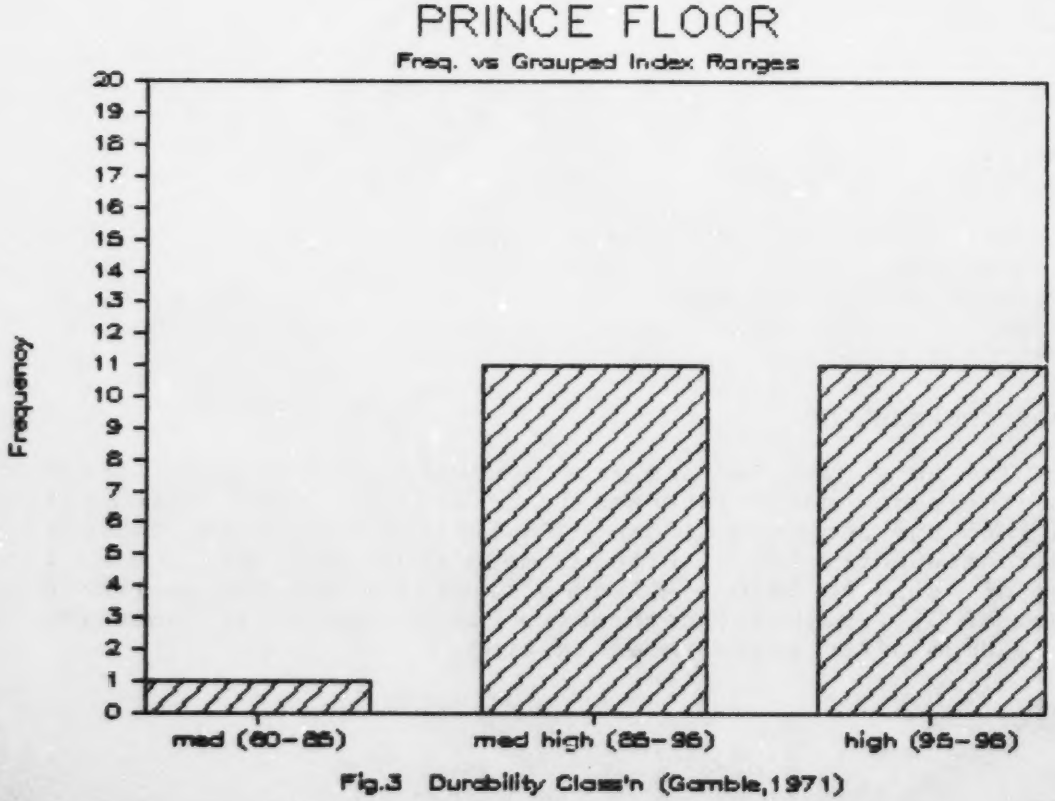

Fig.3 Durability Class'n (Gamble,1971)

Sieve Analyses

As the amount of sample remaining within the drum after testing varied both in volume and size distribution, it was decided that sieve analyses should be run on the more important samples, viz., the floor samples of both mines and the core samples from Lingan-Phelan. It was thought at the time that a definable relationship may be discovered between size distribution and Slake Durability Index. The results of the analyses are documented in Appendex 'E', listing the percentages retained on sieve sizes from 1" down to 0.066" (just under 2mm). There does not appear to be a consistent relationship which would suggest that percentages retained on any one screen reflect sample strength in terms of the Slake Durability Index. Where indications appeared to favour a positive connection in some samples, another would exhibit a contrary trend.

RECOMMENDATIONS

The Slake Durability Index is valuable additional information that should be routinely available to mine management. CBDC should continue building up a database of existing rocks in the lithological units concerned so that in future, comparisons can be made with established, known values. A check of slake indices in the Lingan-Phelan project area, where low values from core samples were obtained, should be done as soon as is practicable in order to verify whether or not the manner in which the sample is obtained has a significant effect on the test results. On the strength of these low index values, other methods should be used here also to determine more precisely the competence and composition of the seat earth material.

To say a rock has a Slake Durability Index of 80 out of a possible 100 may indicate a relatively high strength to the layman - or even to the uninformed mine official - when, in fact, an index of 90 is only 'medium-high' according to Gamble. Further study should be done on the data developed during the contracted testing period in order to explore the possibility of quantitatively describing the rock's strength in respect to some combination of Index, Gamble's description, Degradation value and size distribution of sample particles after testing.

ACKNOWLEDGEMENTS

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APPENDIX 'A'

SLAKE DURABILITY TEST DATA

ID(2) - Slake Durability Index - second cycle
ID(1) - Slake Durability Index - first cycle
D Value - Degree of degradation of residual sample inside drum:
0 - none, 1 - light, 2 - medium, 3 - heavy

SAMPLE NO	CBDC NO	DESCRIPTION	ID(2) %	ID(1) %	D VALUE
		LINGAN..SANDSTONE			
20	LM-1	roof	98.3		0
85	LM-35	"	98.3		0
86	LM-36	"	98.3		0
89	L-30	"	97.7		0
90	L-31	"	98.5		0
		LINGAN..SILTSTONE			
24	LM-5	roof	98.5		0
25	LM-6	"	98.4		0
26	LM-7	"	98.6		0
87	LM-37	"	98.9		0
88	LM-38	"	98.8		0
103	L-44	"	98.9		0
104	L-45	"	98.8		0
105	L-46	"	98.7		0
		LINGAN..MUDSTONE			
21	LM-2	roof	99.0		1
22	LM-3	"	97.8		1
23	LM-4	"	98.2		1
27	LM-8	"	98.5		1
28	LM-9	"	98.3		1
42	LM-30	"	99.0		1
43	LM-31	"	98.8		1
46	LM-34	"	98.8		1
91	L-32	"	98.7		1
92	L-33	"	90.5		3

SAMPLE NO	CBDC NO	DESCRIPTION	ID(2) %	ID(1) %	D VALUE
		LINGAN..COAL			
41	LM-22	coal	98.9		1
45	LM-33	"	98.5		2
106	L-70	"	98.3		1
107	L-71	"	99.0		1
110	L-74	"	98.8		1
113	L-77	"	98.7		1
117	L-81	"	98.5		1
		LINGAN..FLOOR			
29	LM-10	floor; mudstone	94.2		2
30	LM-11	" "	87.4		2
31	LM-12	" "	94.0		2
32	LM-13	" "	93.6		2
33	LM-14	" "	92.3		2
34	LM-15	" "	96.7		1
35	LM-16	" "	95.3		1
36	LM-17	" "	91.9		2
37	LM-18	" "	95.8		1
38	LM-19	" "	92.9		2
39	LM-20	" "	95.4		2
40	LM-21	" "	95.7		2
44	LM-32	" "	94.4		2
94	L-35	floor; shale	89.3		3
95	L-36	" "	94.0		2
96	L-37	" "	86.0		3
97	L-38	" "	91.7		3
98	L-39	" "	91.0		2
99	L-40	" "	97.1		1
100	L-41	" "	88.7		3
101	L-42	" "	94.7		2
102	L-43	" "	87.7		3
108	L-72	" "	84.1		3
109	L-73	" "	82.4		2
111	L-75	" "	97.1		1
112	L-76	" "	94.4		2
114	L-78	" "	71.6		3
115	L-79	" "	91.3		3
116	L-80	" "	96.5		1
		LINGAN..STONE INTRUSION			
93	L-34	stone intrusion	98.2		0

SAMPLE NO	CBDC NO	DESCRIPTION	ID(2) %	ID(1) %	D VALUE
		PRINCE..SANDSTONE			
1	PM-1	roof; sandstone	94.2		0
2	PM-1(A)	" "	94.5		0
11	PM-6	" "	93.9		0
12	PM-6(A)	" "	94.4		0
15	PM-12	" "	95.9		0
16	PM-13	" "	95.7		0
17	PM-14	" "	96.6		0
18	PM-15	" "	96.3		0
19	PM-16	" "	96.3		0
		PRINCE..MUDSTONE			
3	PM-2	roof; mudstone	86.6		3
4	PM-2(A)	" "	84.6		3
7	PM-4	" "	75.0		3
8	PM-4(A)	" "	60.3		3
13	PM-10	" "	91.8		2
14	PM-11	" "	95.1		2
		PRINCE..BETWEEN RIDER & MAIN SEAM			
49	PM-18	roof; mudstone	13.2		3
52	PM-21	" "	22.9		3
59	PM-28	" "	2.1	20.3	3
74	PM-40	" "	1.4	10.8	3
78	PM-44	" "	1.6	11.8	3
		PRINCE..COAL			
60	PM-29	coal	97.1		2
61	PM-30	"	98.4		1
62	PM-31	"	99.4		2
63	PM-32	"	97.5		2
64	PM-33	"	95.8		2
		PRINCE..SPLINT			
65	PM-34	roof	99.1		1
66	PM-35	"	99.0		1

SAMPLE NO	CBDC NO	DESCRIPTION	ID(2) %	ID(1) %	D VALUE
		PRINCE..STONE TROUBLE			
67	PM-36	siltstone	96.4		1
68	PM-37	"	97.6		1
69	PM-38	"	96.4		1
		PRINCE..FLOOR			
5	PM-3	floor; mudstone	95.4		3
6	PM-3(a)	" "	93.4		3
9	PM-5	floor; sandstone	97.9		1
10	PM-5(A)	" "	97.7		1
47	PM-7	floor; siltstone	96.3		1
48	PM-17	floor; mudstone	96.9		1
50	PM-19	" "	95.4		2
51	PM-20	" "	94.7		1
53	PM-22	" "	88.7		2
54	PM-23	" "	96.4		1
55	PM-24	" "	89.0		2
56	PM-25	" "	86.0		2
57	PM-26	" "	83.9		3
58	PM-27	" "	93.9		1
75	PM-41	" "	95.4		1
76	PM-42	" "	94.2		2
77	PM-43	" "	93.4		2
79	PM-45	" "	95.7		1
80	PM-46	" "	90.9		2
81	PM-47	" "	94.8		1
82	PM-48	" "	95.8		1
83	PM-49	" "	95.2		2
84	PM-50	" "	89.2		1
		PHELAN FLOOR..CORE SAMPLES			
70	C-131-1	core	73.9		3
71	C-130-1	"	76.3		3
72	C-129-1	"	84.0		3
73	C-128-1	"	66.4		3

APPENDIX 'B'

DOCUMENTATION OF SAMPLE COLLECTION SITES

SAMPLE NO	CBDC NO	DRY WT grams	COORDINATES NORTH	EAST	VERTICAL LOCATION
			LINGAN..SANDSTONE		
20	LM-1	512.1	11290	10140	15" above seam
85	LM-35	546.6	10300	11200	immediate roof
86	LM-36	553.4	10950	9870	" "
89	L-30	548.3	10300	11250	4' above seam
90	L-31	507.9	"	"	3' " "
			LINGAN..SILTSTONE		
24	LM-5	555.1	11160	8000	94" above seam
25	LM-6	537.1	"	"	90" " "
26	LM-7	487.4	"	"	36" " "
87	LM-37	507.5	10950	9870	5' " "
88	LM-38	552.6	11275	10240	" " "
103	L-44	527.7	10980	11305	4' " "
104	L-45	522.4	"	"	3' " "
105	L-46	561.7	"	"	2' " "
			LINGAN..MUDSTONE		
21	LM-2	466.2	11290	10140	6" above seam
22	LM-3	503.3	11160	8000	12" " "
23	LM-4	497.0	"	"	8" " "
27	LM-8	516.9	"	"	3" " "
28	LM-9	536.3	"	"	4" " "
42	LM-30	541.9	9850	14500	24" " "
43	LM-31	541.9	"	"	immediate roof
46	LM-34	522.6	"	14550	" "
91	L-32	523.1	10340	11250	6" " "
92	L-33	515.7	"	"	12" " "

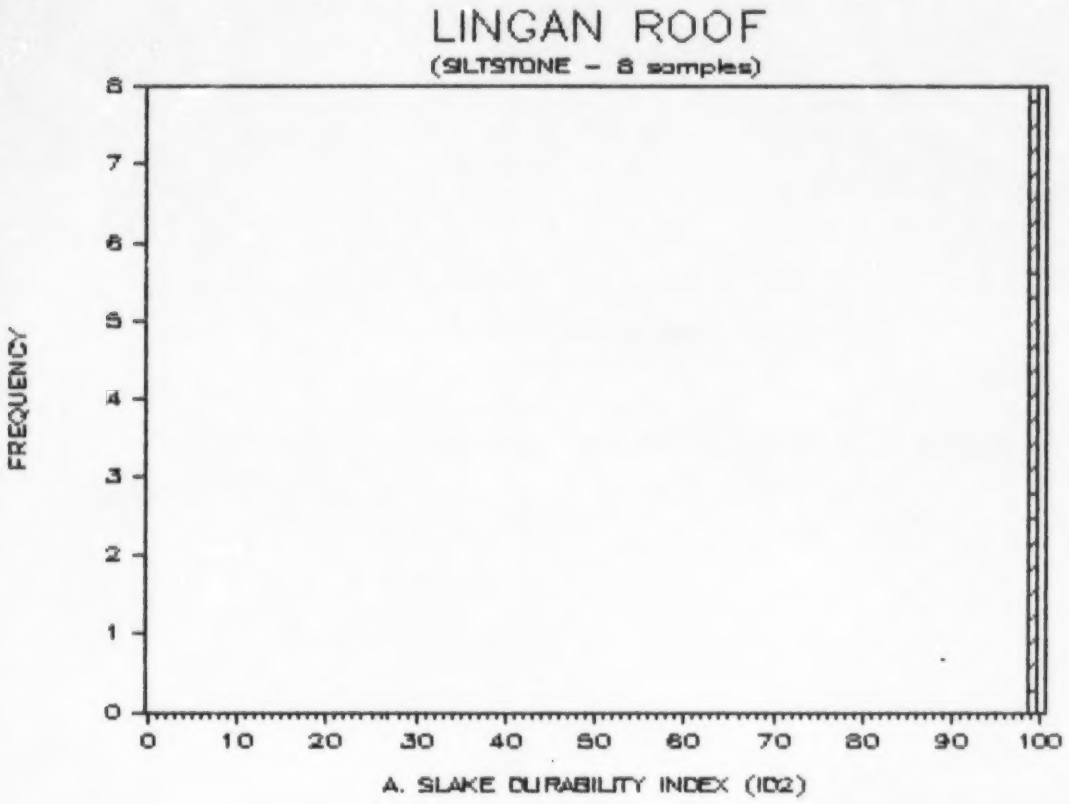
SAMPLE NO	CBDC NO	DRY WT grams	COORDINATES NORTH	EAST	VERTICAL LOCATION
			LINGAN..COAL		
41	LM-22	483.4	11010	7940	2' below roof
45	LM-33	397.5	9850	14550	10" " "
106	L-70	312.7	8 east	S-122	middle of seam
107	L-71	391.0			top 18" of seam
110	L-74	303.6			2' below roof
113	L-77	432.1			lower half of seam
117	L-81	344.6			5" below roof
			LINGAN..FLOOR		
29	LM-10	514.9	10510	7815	6-10" below seam
30	LM-11	518.2	"	"	0-6" " "
31	LM-12	527.0	10540	7825	" " "
32	LM-13	538.0	10640	7850	0-4" " "
33	LM-14	515.3	"	"	4-8" " "
34	LM-15	457.9	10740	7875	0-4" " "
35	LM-16	509.3	"	"	4-8" " "
36	LM-17	501.2	10870	7900	0-6" " "
37	LM-18	514.1	10920	7915	0-8" " "
38	LM-19	500.9	10975	7930	14" " "
39	LM-20	530.7	"	"	0-6" " "
40	LM-21	521.4	"	"	6-14" " "
44	LM-32	470.4	9575	14530	8" " "
94	L-35	496.6	10340	11250	0-6" " "
95	L-36	509.8	10410	11250	" " "
96	L-37	504.3	10480	11270	" " "
97	L-38	456	10530	11270	" " "
98	L-39	503.	10640	11280	" " "
99	L-40	523.2	10680	11290	12" " "
100	L-41	506.7	"	"	6" " "
101	L-42	536.8	10780	11295	" " "
102	L-43	509.9	10830	11300	" " "
108	L-72	510.6	8 east		12" " "
109	L-73	522.7	"		" " "
111	L-75	523.1			4-8" " "
112	L-76	491.0			12" " "
114	L-78	495.1			" " "
115	L-79	508.9			" " "
116	L-80	525.5			4-10" " "
			LINGAN..STONE INTRUSION		
93	L-34	545.6	10340	11250	stone intrusion

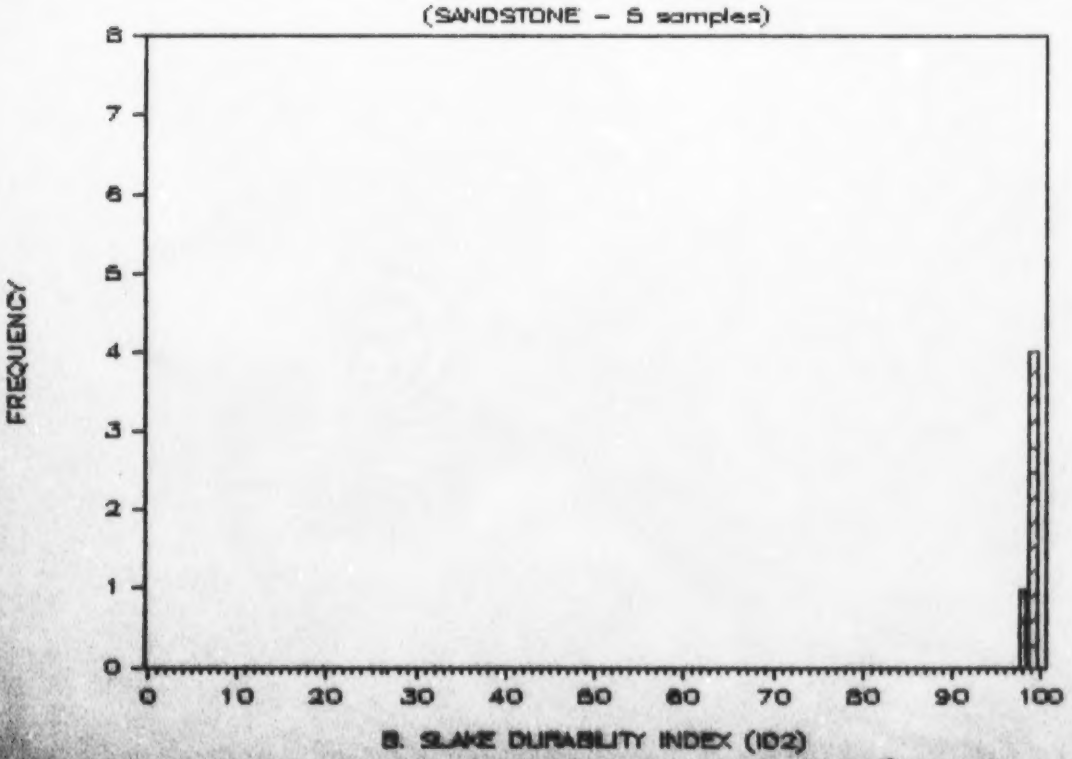
SAMPLE NO	CBDC NO	DRY WT grams	COORDINATES NORTH	COORDINATES WEST	VERTICAL LOCATION
			PRINCE..SANDSTONE		
1	PM-1	515.5	40350	54165	2' above seam
2	PM-1(A)	494.4	"	"	" " "
11	PM-6	419.1	"	"	" " "
12	PM-6(A)	391.6	"	"	" " "
15	PM-12	503.4	40400	54170	3' " "
16	PM-13	493.7	"	"	2' " "
17	PM-14	532.9	"	"	30" " "
18	PM-15	491.4	39920	53990	2' " "
19	PM-16	517.4	"	"	1' " "
			PRINCE..MUDSTONE		
3	PM-2	504.6	39175	52550	first 6" of roof
4	PM-2(A)	454.3	"	"	" " " "
7	PM-4	431.6	"	"	" " " "
8	PM-4(A)	427.0	"	"	" " " "
13	PM-10	518.7	39170	52330	immediate roof
14	PM-11	502.2	39170	52390	" "
			PRINCE..BETWEEN RIDER & MAIN SEAM		
49	PM-18	498.6	37375	51840	between
52	PM-21	474.0	37420	51805	rider
59	PM-28	502.2	37610	51660	and
74	PM-40	472.3	37460	51970	main
78	PM-44	495.7	37560	51885	seam
			PRINCE..COAL		
60	PM-29	363.3	37500	51750	bottom of wall
61	PM-30	366.9	"	"	" " "
62	PM-31	454.9	"	"	12" below roof
63	PM-32	391.7	39975	54000	top half of seam
64	PM-33	358.6	"	"	bottom " " "

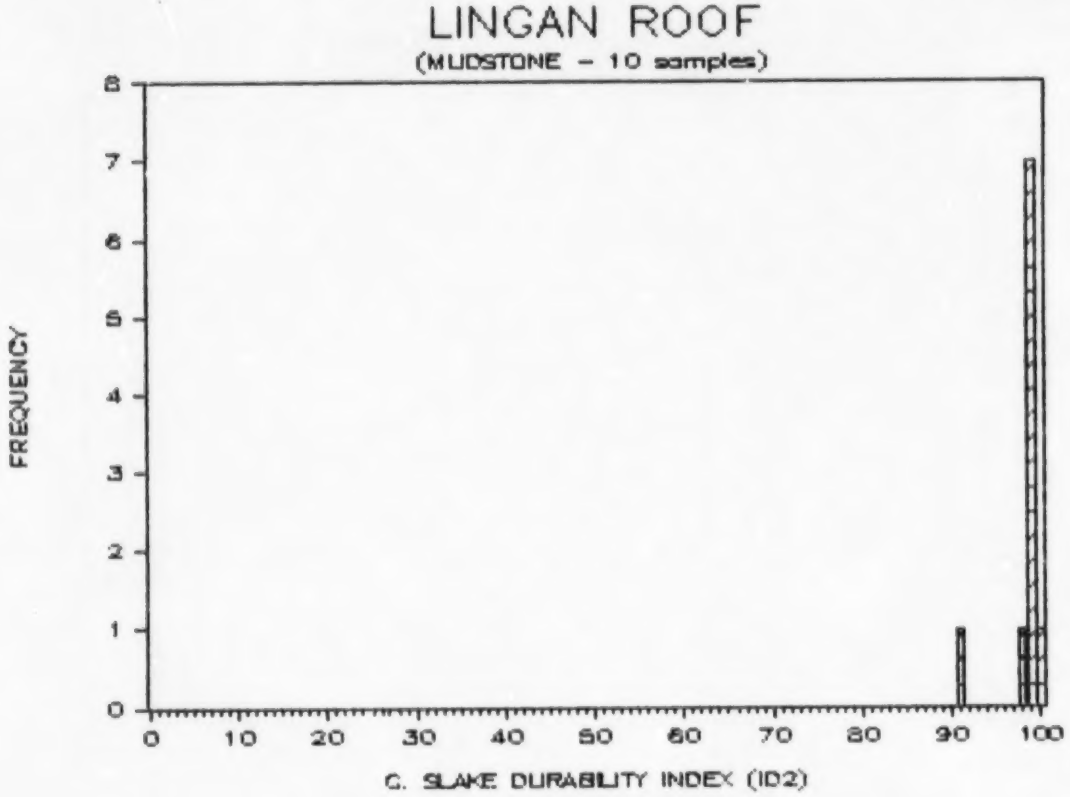
SAMPLE NO	CBDC NO	DRY WT grams	COORDINATES NORTH	COORDINATES WEST	VERTICAL LOCATION
			PRINCE..SPLINT		
65	PM-34	509.0	39530	53625	20-24" above seam
66	PM-35	499.3	"	"	4" " "
			PRINCE..STONE TROUBLE		
67	PM-36	510.5	40440	54175	stone trouble
68	PM-37	543.1	"	"	" "
69	PM-38	517.8	"	"	" "
			PRINCE..FLOOR		
5	PM-3	505.9	39920	53990	10" below seam
6	PM-3(A)	473.6	"	"	" " "
9	PM-5	500.8	40350	54165	6" " "
10	PM-5(A)	473.3	"	"	" " "
47	PM-7	523.0	"	"	immediate floor
48	PM-17	509.2	37375	51840	" "
50	PM-19	495.7	37400	51835	" "
51	PM-20	522.0	37420	51805	" "
53	PM-22	527.9	37440	51790	" "
54	PM-23	529.9	37460	51775	" "
55	PM-24	503.8	37530	51715	" "
56	PM-25	518.8	"	"	" "
57	PM-26	513.0	37575	51680	" "
58	PM-27	435.3	37610	51660	" "
75	PM-41	544.6	37490	51950	" "
76	PM-42	515.2	37540	51915	" "
77	PM-43	541.4	"	"	" "
79	PM-45	525.3	37585	51870	" "
80	PM-46	541.3	37610	51850	" "
81	PM-47	492.8	"	"	" "
82	PM-48	543.6	37650	51815	" "
83	PM-49	498.7	37670	51800	" "
84	PM-50	516.8	37710	51775	" "
			PHELAN SEAM..CORE SAMPLES		
70	C-131-1	541.2	291'7" - 293 '8"		
71	C-130-1	488.6	173'11"-174'9" & 176'1"-176'9"		
72	C-129-1	552.9	400'8"-401'6.5" & 401'11.5"-402'9.5"		
73	C-128-1	503.5	526'9"-527'0" & 527'10"-528'9"		

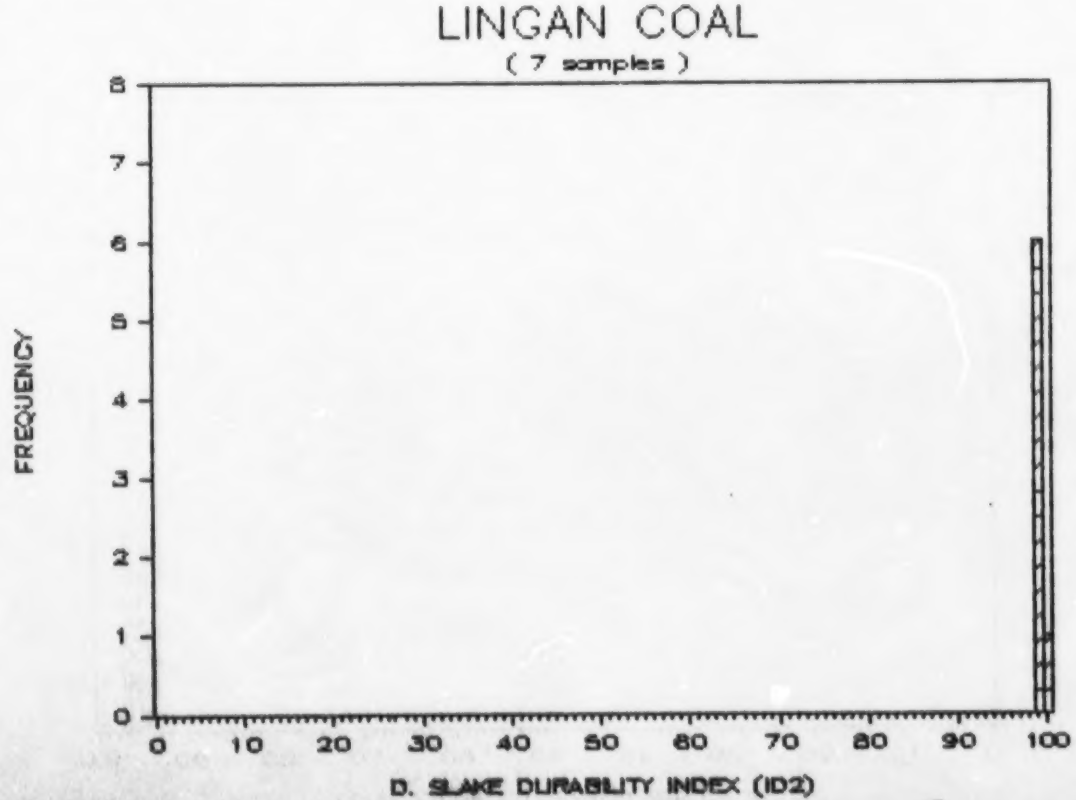
APPENDIX 'C'

GRAPHS - SLAKE DURABILITY INDICES vs FREQUENCIES


LINGAN ROOF
(SILTSTONE - 8 samples)
FREQUENCY
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
A. SLAKE DURABILITY INDEX (ID2)

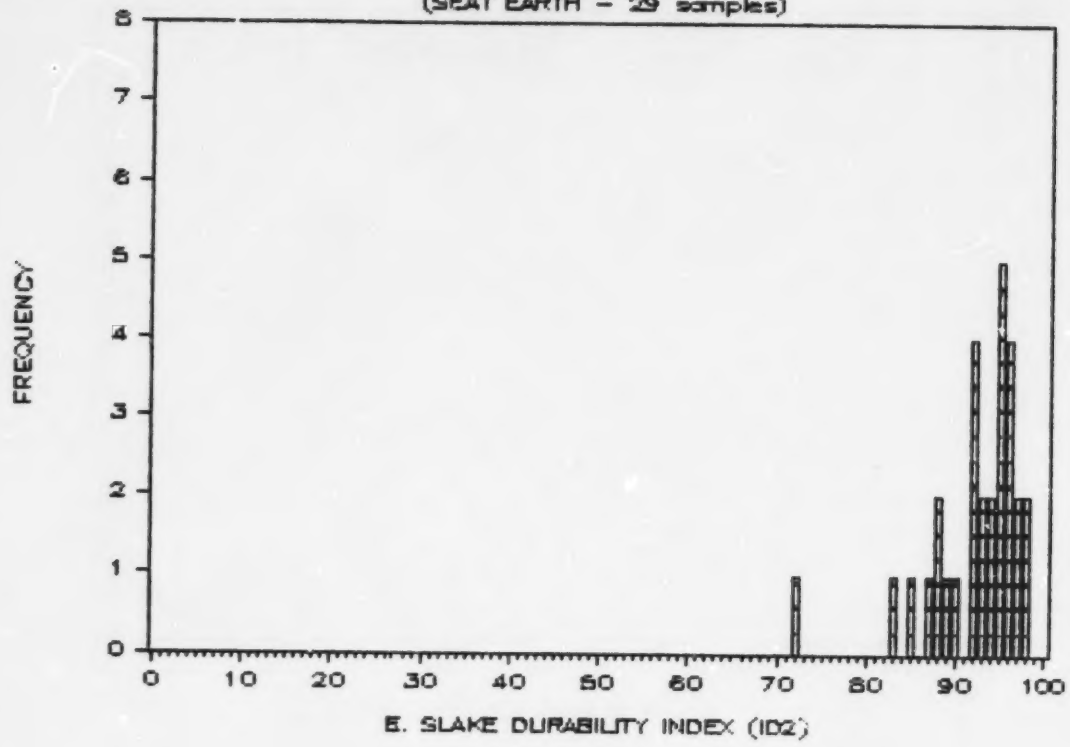

LINGAN ROOF
(SANDSTONE - 5 samples)
FREQUENCY
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
B. SLAKE DURABILITY INDEX (ID2)


LINGAN ROOF
(MUDSTONE - 10 samples)
FREQUENCY
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
C. SLAKE DURABILITY INDEX (ID2)


LINGAN COAL
(7 samples)
FREQUENCY
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
D. SLAKE DURABILITY INDEX (ID2)

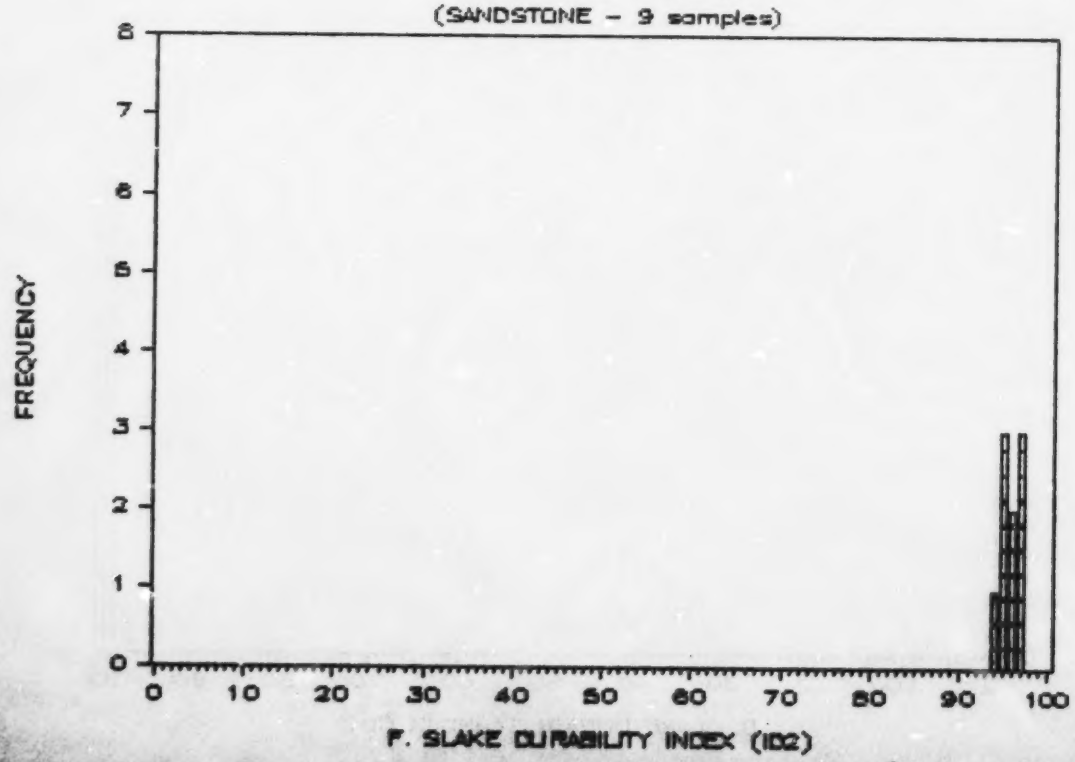
LINGAN FLOOR

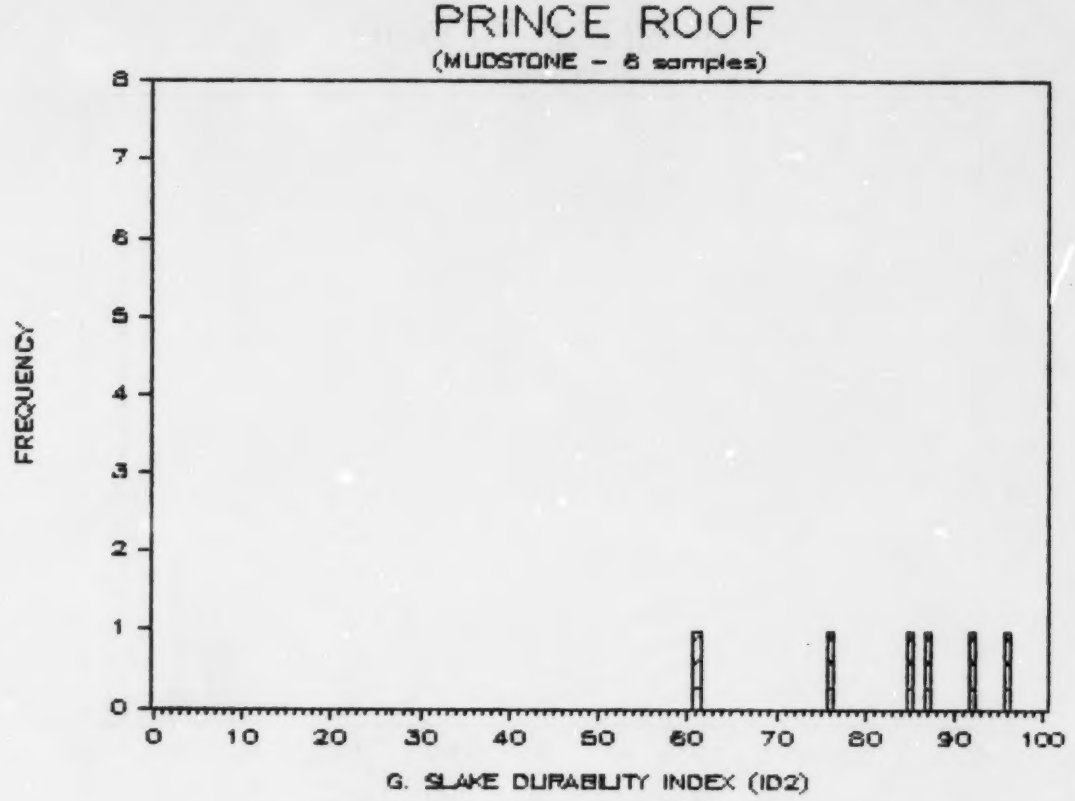
(SEAT EARTH – 29 samples)

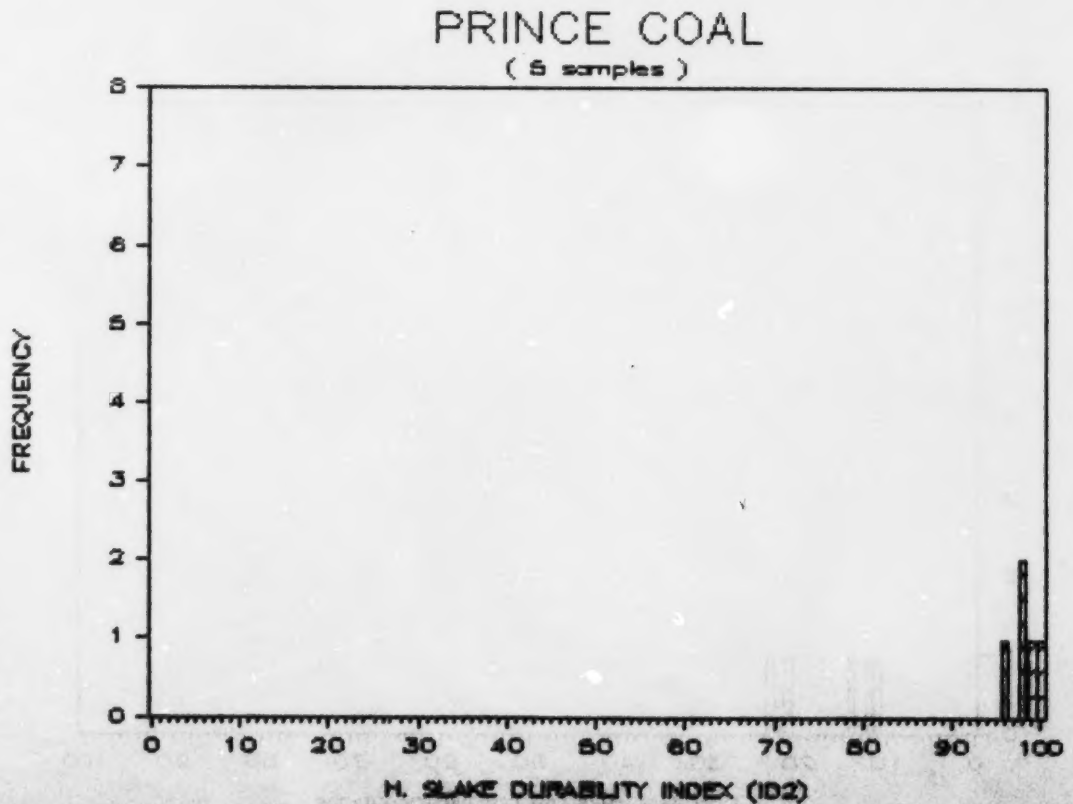


PRINCE ROOF

(SANDSTONE – 9 samples)

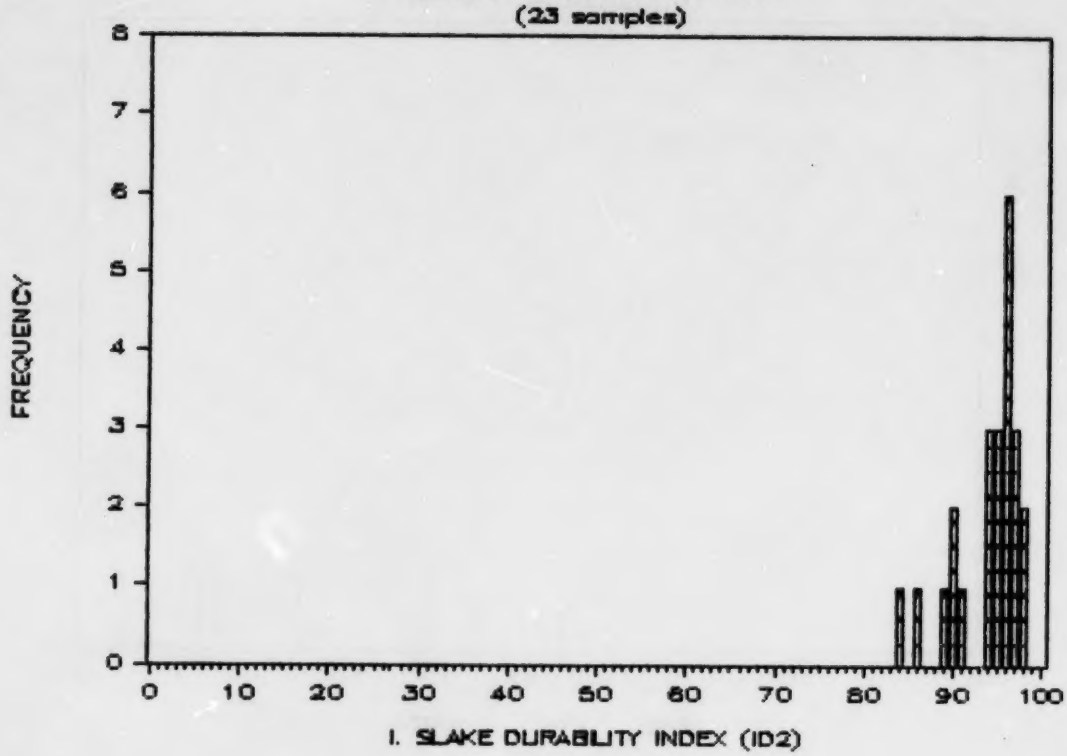



PRINCE ROOF
(MUDSTONE - 6 samples)
FREQUENCY
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
G. SLAKE DURABILITY INDEX (ID2)


PRINCE COAL
(6 samples)
FREQUENCY
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
H. SLAKE DURABILITY INDEX (ID2)

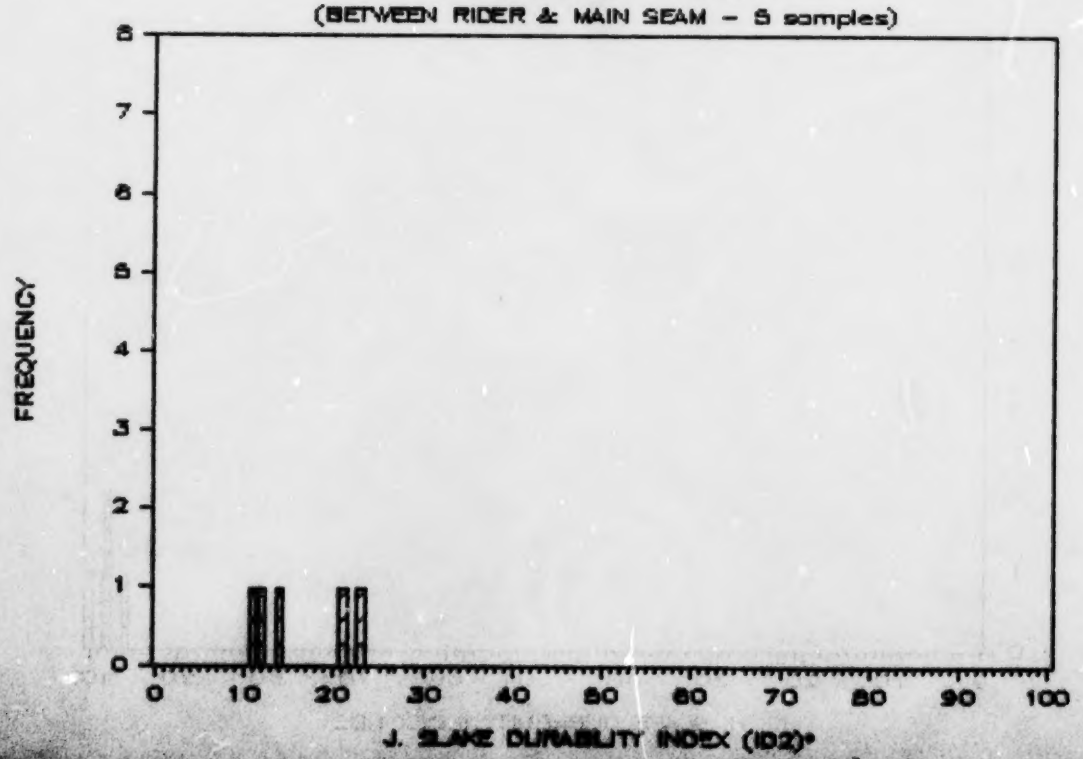
PRINCE FLOOR

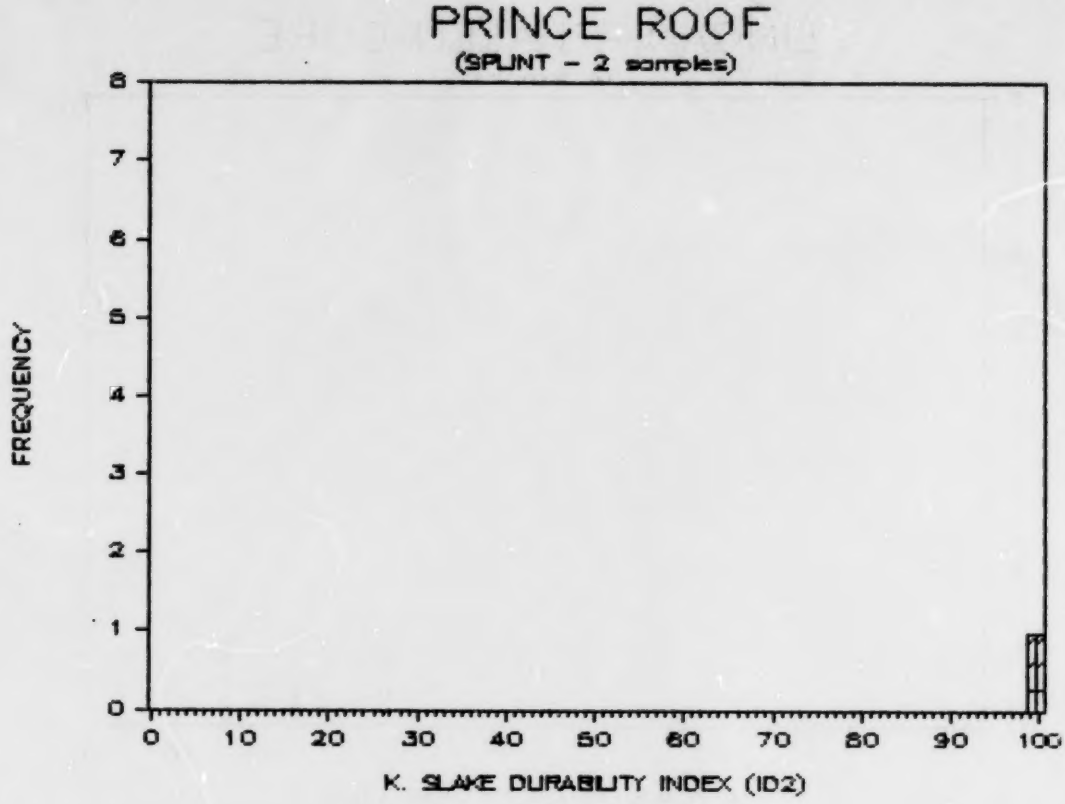
(23 samples)

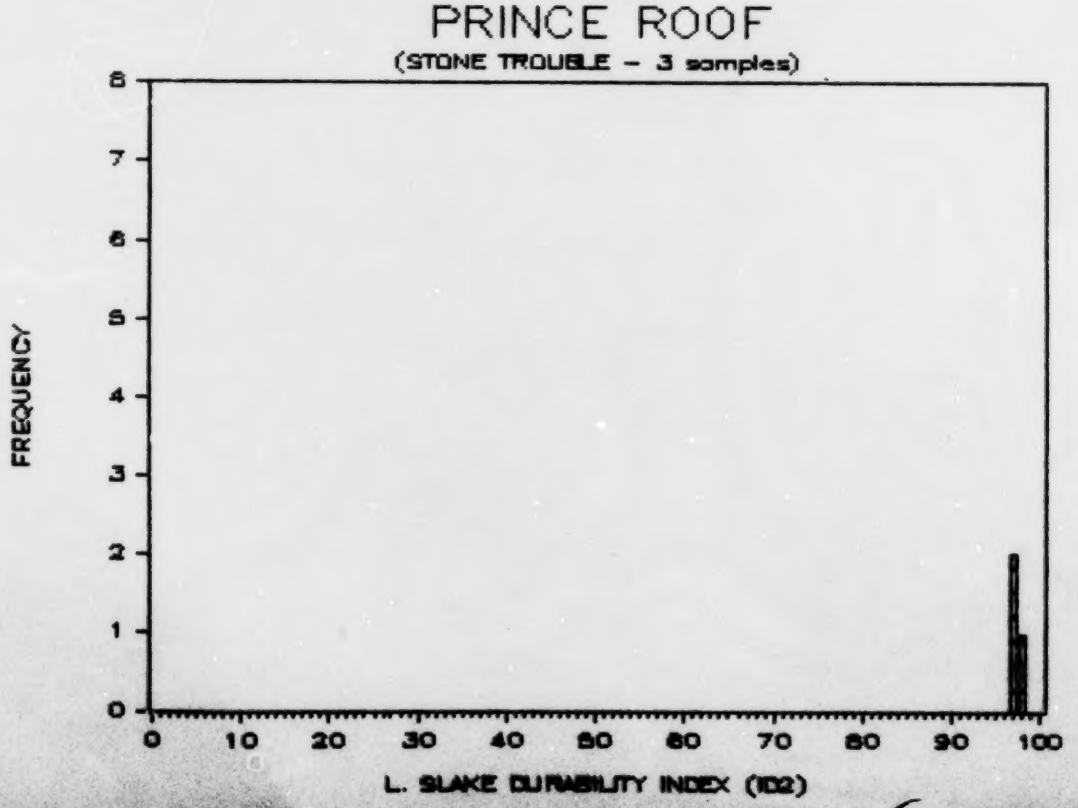


PRINCE ROOF

(BETWEEN RIDER & MAIN SEAM – 5 samples)

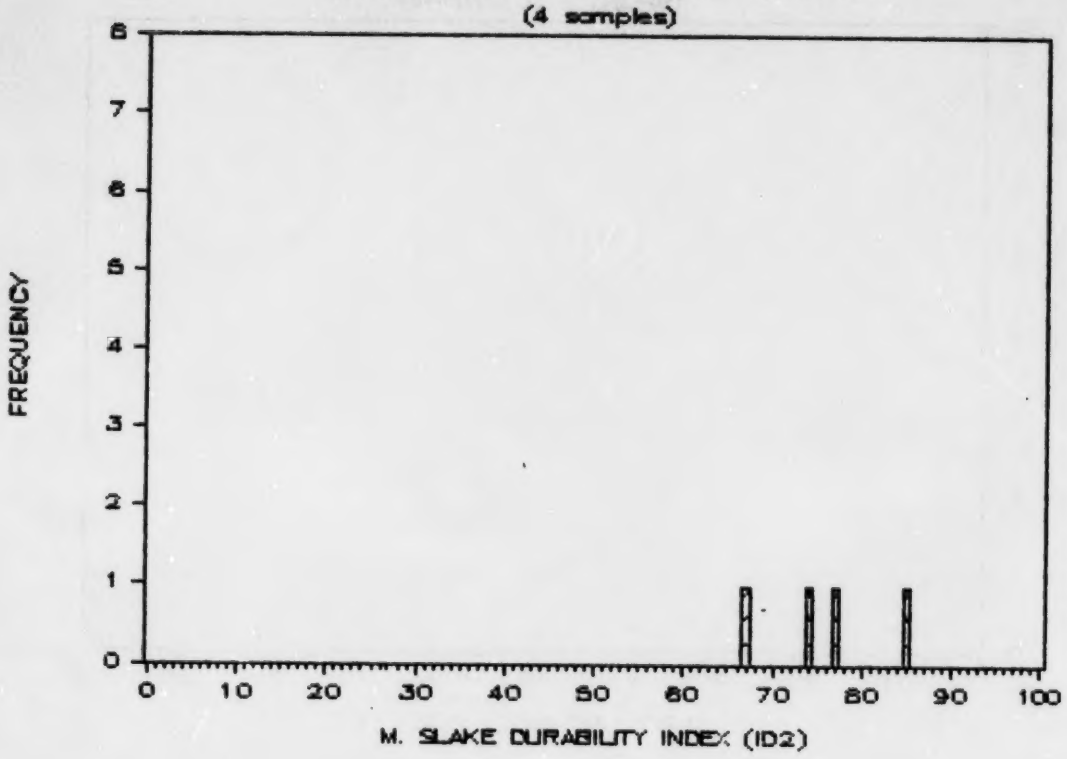



PRINCE ROOF
(SPLINT - 2 samples)
FREQUENCY
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
K. SLAKE DURABILITY INDEX (ID2)


PRINCE ROOF
(STONE TROUBLE - 3 samples)
FREQUENCY
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100
L. SLAKE DURABILITY INDEX (ID2)

LINGAN–PHALEN CORE

(4 samples)



APPENDIX 'D'

DOCUMENTATION OF TEST CONDITIONS

SLAKING FLUID: Tap water at 20 degrees celsius +/- 1 degree was used as the slaking fluid.

DRYING TEMPERATURE: The drying oven was maintained at a temperature of 105 degrees celsius +/- 3 degrees.

SAMPLE NO	DESCRIPTION OF MATERIAL IN TROUGH AND DRUM	
	PASSING THROUGH DRUM	REMAINING INSIDE DRUM
1	fine to v.fine-grained sand	/no fragments sample well-rounded
2	----"---------"------	/--------"----------"---------
3	angular fragments,very fine to v.coarse sand	/ sub-angular fragments
4	------"---------"------	/ -----"----------"---------
5	15% fine to v. coarse angular fragments	/ -----"----------"---------
6	------"---------"------	/ -----"----------"----------
7	v. fine to v.coarse angular, 25% < 200 Mesh	/ sample completely fragmented, / sub-rounded
8	------"---------"------	/ -----"----------"----------
9	60% < 200 Mesh,fine grains	/ v.few sub-angular fragments
10	------"---------"------	/ -----"----------"----------
11	fine-v.fine sand	/ no fragments - original sample / rounded
12	------"---------"------	/ -----"----------"----------
13	v.coarse angular sand	/ slabby,sub-angular fragments
14	------"---------"------	/ -----"----------"----------
15	25% < 200 Mesh fine to v.fine sand	/ no fragments - original sample / rounded

SAMPLE NO	DESCRIPTION OF MATERIAL IN TROUGH AND DRUM	
	PASSING THROUGH DRUM	REMAINING INSIDE DRUM
16	15% < 200 Mesh fine to v.fine sand	no fragments, original sample rounded
17	fine to v.fine sand	-"-"-
18	-"-"-	-"-"-
19	-"-"-	-"-"-
20	-"-"-	-"-"-
21	-"-"-	v. little fragmentation, original sample rounded
22	fine to v.coarse sand - angular	some sub-angular, slabby fragments
23	-"-"-	v.little fragmentation - sub-angular
24	v.fine to medium sand	v. little fragmentation, original sample rounded
25	v. fine to fine angular grains	no fragmentation,original sample rounded
26	-"-"-	-"-"-
27	v. fine to v. coarse, angular	some sub-angular fragmentation
28	-"-"-	-"-"-
29	med to v. coarse angular grains	slabby, sub-angular fragments
30	-"-"-	-"-"-
31	fine to v. coarse angular grains	-"-"-
32	-"-"-	sub-angular fragments
33	-"-"-	sub-angular,slabby fragments
34	-"-"-	sub-angular to sub-rounded fragments

SAMPLE NO	DESCRIPTION OF MATERIAL IN TROUGH AND DRUM	
	PASSING THROUGH DRUM	REMAINING INSIDE DRUM
35	v. fine to v. coarse angular grains	slabby,sub-angular fragments
36	med to v. coarse angular grains	-------"---------"-------
37	fine to v. coarse angular grains	slabby, angular to sub-angular fragments
38	med to v. coarse angular grains	------"---------"-------
39	v. fine to v. coarse, angular	slabby,sub-angular
40	-----"-------"------	------"---------"-------
41	fine to v. coarse, angular	angular fragments
42	v. fine to med, angular	v. little fragmentation, sub-angular fragments
43	60% v. fine to coarse angular sand	-------"---------"-------
44	v. fine to v. coarse angular sand	sub-angular to angular
45	v. fine to v. coarse blocky,angular	angular, blocky fragments
46	60% v. fine to med grains	some sub-angular fragments
47	60% v. fine to coarse	some sub-angular, slabby
48	50% v. fine to v. coarse	some sub-angular fragments
49	fine to v. coarse,angular	complete fragmentation angular to sub-angular
50	v. fine to v. coarse, angular	sub-angular fragments
51	------"-------"--------	------"--------"--------

SAMPLE NO	DESCRIPTION OF MATERIAL IN TROUGH AND DRUM PASSING THROUGH DRUM	REMAINING INSIDE DRUM
52	v. fine to v. coarse, angular fragments	90% fragmented,remainder sub-rounded
53	fine to v. coarse, angular	slabby, sub-angular
54	v. fine to coarse, angular	sub-angular
55	v. fine to v. coarse, angular	slabby, sub-angular
56	v. fine to coarse, angular	-------"---------"-------
57	-------"-------"-------	sub-angular
58	fine to coarse, angular	slabby, sub-angular
59	v. fine to med,angular	totally fragmented, small sub-angular fragments
60	v. fine to coarse, angular	blocky, angular fragments
61	-------"-------"-------	-------"---------"-------
62	fine to coarse, angular	-------"---------"-------
63	fine to med, angular	-------"---------"-------
64	v. fine to med, angular	-------"---------"-------
65	v. fine to coarse,angular	-------"---------"-------
66	v. fine to coarse	some sub-angular fragments
67	40% v. fine to coarse	some angular fragments
68	v. fine to coarse, angular	angular fragments
69	v. fine to med, angular	some slabby, angular fragments
70	fine to v. coarse, angular	heavily fragmented - angular to sub-angular
71	fine to v. coarse, angular	sub-angular

SAMPLE NO	DESCRIPTION OF MATERIAL IN TROUGH AND DRUM	
	PASSING THROUGH DRUM	REMAINING INSIDE DRUM
72	fine to v. coarse, angular	heavily fragmented, sub-angular to sub-rounded
73	med to v. coarse, angular	95% fragmentation,sub-angular
74	fine to med. angular	totally fragmented, sub-angular
75	v. fine to coarse, angular	slabby,sub-angular fragments
76	v. fine to v. coarse, angular	some sub-angular fragments
77	v. fine to coarse,angular	slabby,sub-angular fragments
78	v. fine to med, angular	totally fragmented, sub-angular
79	v. fine to v. coarse, angular	some, sub-angular fragments
80	fine to v. coarse, angular	med fragmentation,slabby, sub-angular
81	v. fine to v. coarse, angular	some, sub-angular fragments
82	-------"-------"-------	--------"---------"--------
83	-------"-------"-------	slabby, sub-angular
84	fine to v. coarse,angular	sub-angular fragments
85	v.fine to fine grains	v. little fragmentation
86	-------"-------"-------	--------"---------"--------
87	v. fine to coarse, angular	--------"---------"--------
88	v. fine to med, angular	--------"---------"--------
89	v. fine sand	no fragmentation
90	-------"-------"-------	--------"---------"--------

SAMPLE NO	DESCRIPTION OF MATERIAL IN TROUGH AND DRUM PASSING THROUGH DRUM	REMAINING INSIDE DRUM
91	v. fine to med	little fragmentation
92	v. fine to v. coarse, angular	med fragmentation,sub-angular
93	v. fine to fine	no fragmentation
94	med to v. coarse, angular	heavy fragmentation,sub-angular
95	v. fine to coarse, angular	sub-angular fragments
96	-----"---------"--------	heavy fragmentation,angular and sub-angular
97	fine to v. coarse,angular	heavy fragmentation, sub-angular
98	med to v. coarse, angular	sub-angular fragments
99	v. fine to v. coarse, angular	med fragmentation,sub-angular to sub-rounded
100	-----"---------"--------	heavily fragmented,sub angular
101	fine to v. coarse,angular	some, sub-angular fragments
102	-----"---------"--------	med , sub-angular fragments
103	fine to med grains	no fragmentation
104	-----"---------"--------	-------"---------"--------
105	v. fine to fine grains	-------"---------"--------
106	v. fine to med grains	little fragmentation
107	v. fine to coarse,angular	-------"---------"--------
108	fine to v. coarse, angular	heavily fragmented,angular to sub-angular
109	fine to coarse, angular	med fragmentation sub-angular

SAMPLE NO	DESCRIPTION OF MATERIAL IN TROUGH AND DRUM PASSING THROUGH DRUM	REMAINING INSIDE DRUM
110	v. fine to med, angular fragments	little fragmentation, angular
111	v. fine to coarse, angular	little fragmentation
112	-------"-------"--------	med fragmentation, sub-angular
113	fine to coarse, angular	little fragmentation, angular
114	fine to v. coarse, angular	heavily fragmented, sub-angular
115	-------"-------"--------	heavily fragmented, angular and sub-angular
116	-------"-------"--------	little fragmentation, angular and sub-angular
117	v. fine to coarse, angular	little fragmentation, angular

APPENDIX 'E'

SIEVE ANALYSES - LINGAN MINE FLOOR SAMPLES

CBDC NO	SAMPLE WT(g)	PERCENTAGES RETAINED ON SIEVES (inches) 1.0	0.75	0.5	.375	.223	.094	.066	PAN
LM-10	487.5	89.1	0.0	4.1	1.3	2.1	2.6	0.3	0.2
LM-11	455.5	56.8	7.2	14.2	5.3	8.1	7.0	1.0	0.5
LM-12	497.8	72.7	12.6	2.3	1.9	5.1	4.4	0.5	0.4
LM-13	506.4	73.6	11.3	4.0	3.4	2.5	4.2	0.5	0.4
LM-14	478.4								
LM-15	444.8	78.1	17.2	2.3	0.4	0.7	0.9	0.1	0.2
LM-16	487.4	80.0	10.4	4.9	1.0	1.3	1.9	0.3	0.3
LM-17	462.6	55.9	16.5	9.0	5.2	5.7	6.1	0.9	0.6
LM-18	494.3	83.1	2.8	7.0	2.1	2.7	1.7	0.3	0.4
LM-19	467.2	66.4	14.9	10.5	1.2	2.8	3.3	0.5	0.3
LM-20	507.6	71.2	20.4	1.7	2.0	2.0	2.2	0.3	0.3
LM-21	500.8	76.3	16.6	0.0	2.0	2.3	2.1	0.4	0.3
L-32	519.3	97.4	1.9	0.0	0.2	0.2	0.1	0.1	0.1
L-35	443.9	46.8	33.0	4.8	1.5	6.0	7.0	0.7	0.2
L-36	480.4	71.5	12.3	6.2	3.0	3.3	3.0	0.4	0.2
L-37	435.2	35.2	21.0	11.7	8.3	12.7	9.2	1.3	0.6
L-38	421.4	25.1	34.9	22.4	3.7	5.9	6.3	0.9	0.6
L-39	461.9	45.4	31.3	7.1	3.8	5.2	5.9	0.8	0.5
L-40	452.4	93.8	3.1	0.6	0.5	0.5	1.2	0.1	0.1
L-41	450.8	31.6	26.7	17.4	5.8	8.0	8.4	1.3	0.8
L-42	478.6	74.5	5.5	8.2	1.9	2.8	5.8	0.9	0.4
L-43	448.6	54.4	23.9	2.4	3.5	7.0	7.4	0.9	0.5
L-72	430.2	4.4	36.6	15.2	8.6	14.6	16.9	2.3	1.5
L-73	431.9	54.9	11.6	2.8	6.4	9.5	12.4	1.7	0.6
L-75	508.6	95.6	0.0	3.1	0.0	3.0	0.7	0.1	0.02
L-78	355.5	44.2	10.9	1.9	3.5	13.6	21.8	3.5	0.6
L-79	465.4	55.5	15.3	10.3	3.3	7.5	6.5	1.0	0.6
L-80	507.6	96.7	2.5	0.0	0.0	0.1	0.6	0.1	0.04

SIEVE ANALYSES - PRINCE MINE FLOOR SAMPLES

CBDC NO	SAMPLE WT(g)	PERCENTAGES RETAINED ON SIEVES (inches) 1.0	0.75	0.5	.375	.223	.094	.066	PAN
PM-3	483.4	93.1	2.7	2.3	0.0	1.0	0.9	0.1	0.1
PM3(A)	442.1	56.2	32.3	4.0	1.6	2.7	2.7	0.2	0.1
PM-5	491.9	99.7	0.0	0.0	0.0	0.2	0.1	0.02	0.04
PM5(A)	463.5	99.8	0.0	0.0	0.0	0.2	0.04	0.0	0.02
PM-7	504.8	90.4	8.6	0.0	0.6	0.2	0.2	0.0	0.03
PM-17	494.8	96.4	1.8	0.6	0.0	0.6	0.5	0.04	0.04
PM-19	475.7	81.3	5.2	7.2	1.8	2.0	1.9	0.3	0.3
PM-20	496.2	90.7	2.2	1.5	1.7	1.7	1.6	0.2	0.2
PM-22	470.4	61.3	9.0	11.8	3.4	7.2	6.3	0.6	0.4
PM-23	512.0	97.1	0.0	1.2	0.4	0.5	0.6	0.03	0.05
PM-24	450.2	53.9	13.9	12.8	3.7	8.8	5.5	0.7	0.7
PM-25	440.4	55.2	17.5	8.7	5.7	6.4	5.4	0.5	0.5
PM-26	432.9	53.3	10.6	12.4	3.3	8.2	10.1	1.2	0.7
PM-27	410.5	77.4	7.6	8.8	0.8	2.5	2.4	0.2	0.1
PM-41	520.6	93.6	0.0	2.0	1.5	1.2	1.6	0.1	0.06
PM-42	487.7	74.9	16.0	2.3	1.6	2.1	2.7	0.2	0.1
PM-43	508.2	71.9	12.8	5.2	2.7	3.3	3.2	0.4	0.4
PM-45	504.1	91.5	4.3	0.0	1.6	1.2	1.1	0.1	0.1
PM-46	494.2	75.2	11.1	2.9	1.5	4.5	4.1	0.5	0.3
PM-47	468.9	90.6	6.3	0.0	0.9	1.3	0.7	0.1	0.04
PM-48	522.1	96.4	0.0	0.8	0.4	1.4	0.6	0.05	0.03
PM-49	476.0	87.4	8.1	1.5	1.3	0.6	1.0	0.06	0.04
PM-50	462.7	86.8	0.0	3.0	2.1	3.5	4.1	0.5	0.2

CORE SAMPLES...LINGAN PHELAN

C131-1	403.7	0.0	9.5	2.8	3.1	27.9	49.5	6.1	1.1
C130-1	377.6	55.4	4.1	8.1	5.3	5.5	17.8	3.1	0.5
C129-1	468.1	19.5	18.2	11.1	4.0	18.2	25.6	2.7	0.6
C128-1	340.1	0.0	0.0	9.5	3.5	24.5	53.5	7.4	1.4